Observations of deep convective influence on stratospheric water vapor and its isotopic composition

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Hydration pathways

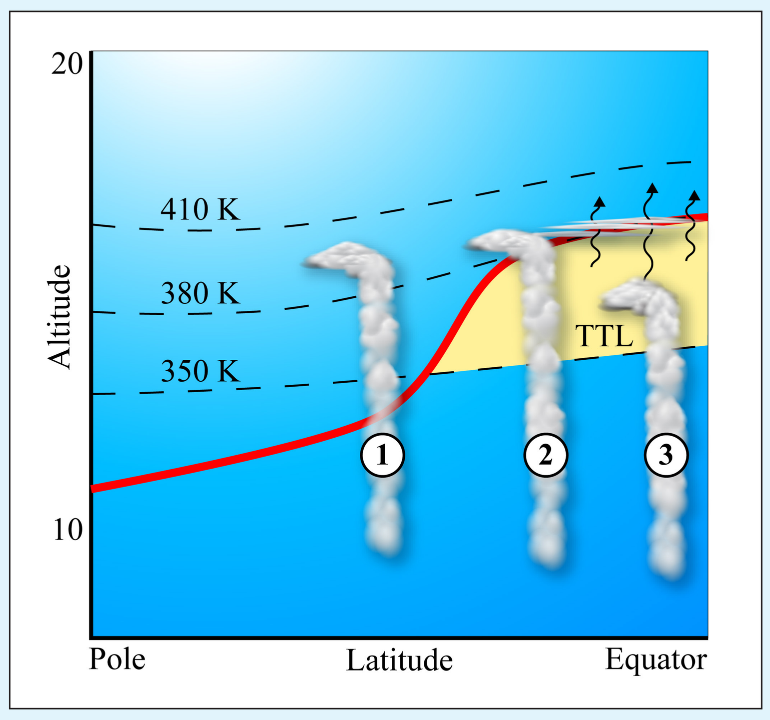
H_2O and H_2O isotopes observations can be used to quantify:

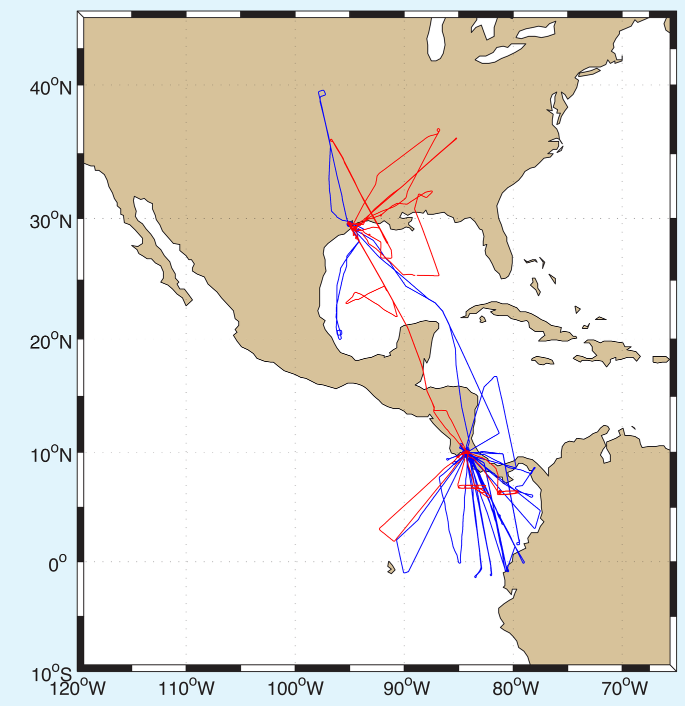
1. Ice lofting and convective outflow above 380 K in mid-lats
2. Ice lofting into the tropical stratosphere
3. Convective influence in the TTL

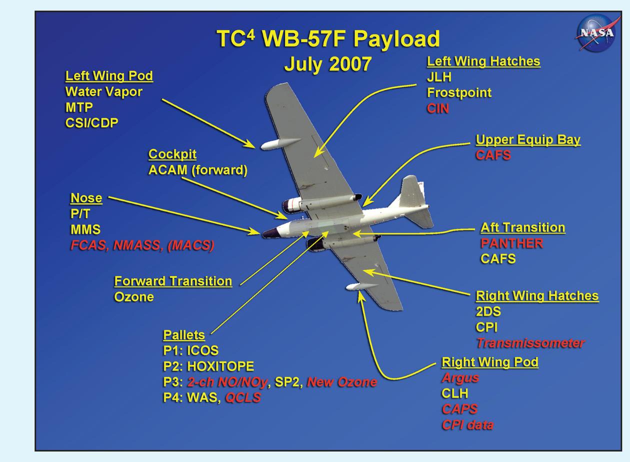
We have observational evidence for each of these three pathways. We focus on Pathway 1: What fraction of mid-latitude stratospheric water vapor results from deep convection?

How will this input change with increased greenhouse gases and climate forcings?

What is the impact of this input on ozone photochemistry?







Observations of the Harvard in situ water isotope instruments (ICOS and Hoxotope) were obtained on the NASA WB57 during AVE_WIIF, CRAVE, and TC4.

Blue lines: CRAVE Winter 2006.
Red lines: AVE_WIIF and TC4, Summer 2005 and 2007.

TTL Convection

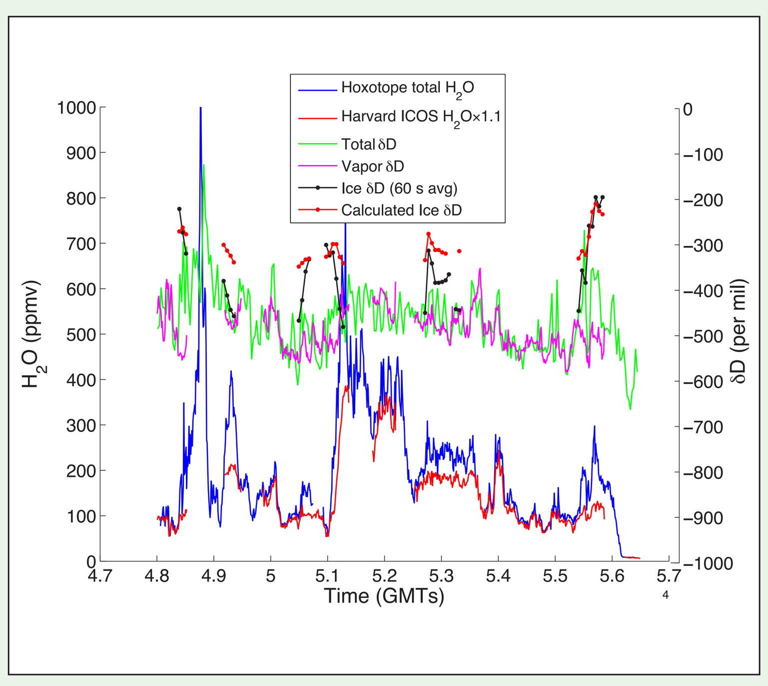


FIGURE 1. In situ observations in a TTL cirrus during TC4 in the Eastern tropical pacific, altitude 12 –14 km. The total (vapor + condensed) and vapor phase observations are used to determine the isotope ratio of the condensed phase.

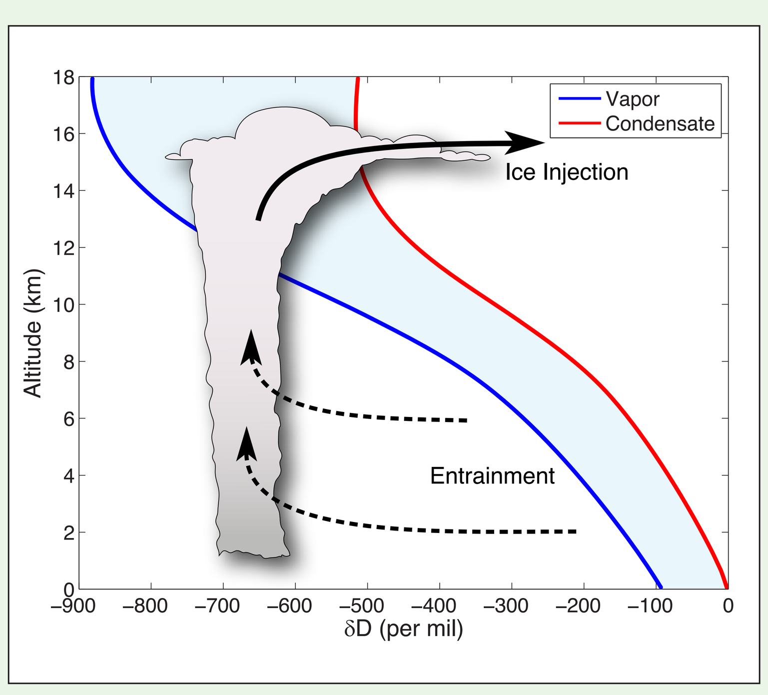


FIGURE 2. The calculated isotope ratio of water vapor and the condensate using the Rayleigh fractionation model is shown in blue and red lines. In the absence of convective input we expect the isotope ratio of the observations to lie somewhere between these two lines. Observations of isotope ratios heavier than the Rayleigh model prediction (ie closer to zero) are consistent with convective injection of water from lower altitudes where the isotope ratio is closer to zero. The observations of 20080808 are consistent of injection of water from 6 – 8 km.

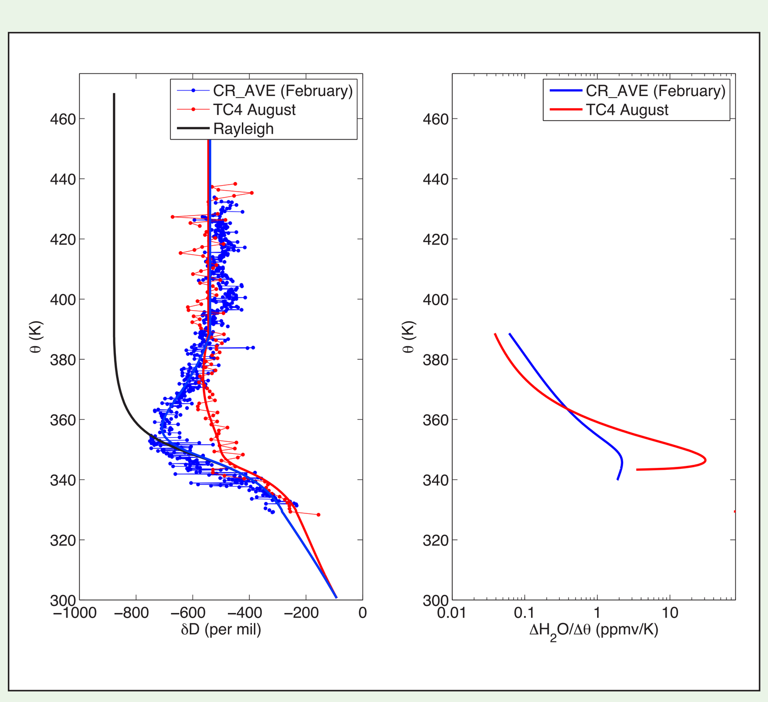


FIGURE 3. The observed and modeled isotope ratios are shown on the left for winter (blue) and summer (red). The black line represent the Rayleigh model (no convection) and the blue and red lines represent a Rayleigh model with convective injection of ice. The shift towards zero away from the Rayleigh curve results from the convective injection of ice. The right hand side shows the quantity of ice added in the model calculations. The amount of ice needed to reproduce the summertime observations is a factor of 20 times greater than in winter.

Mid Latitude Convection

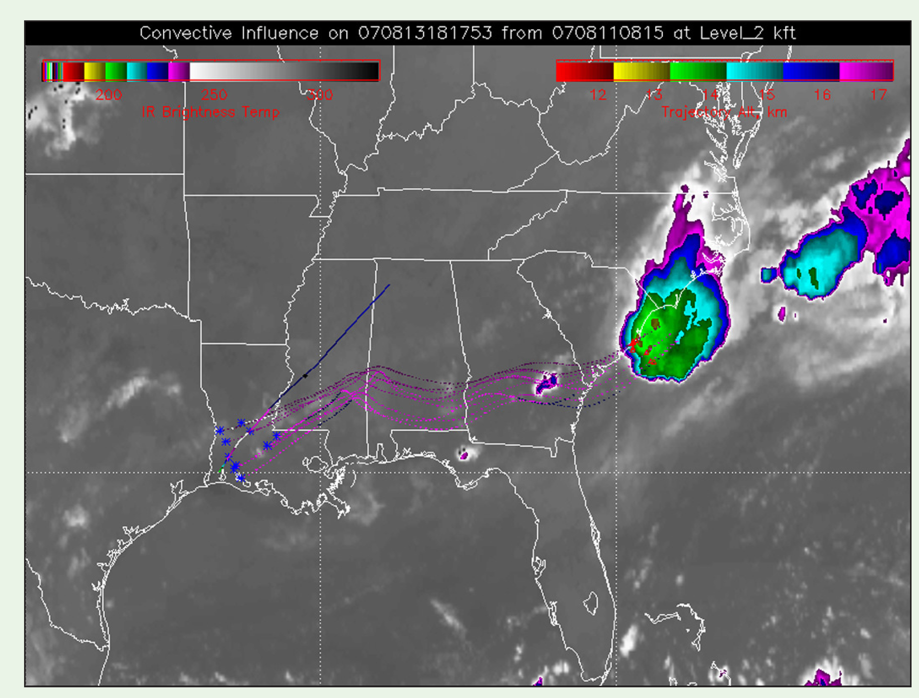


FIGURE 4. GOES IR image of a storm system near South Carolina on 20080811. The straight blue line is the flight path of the WB57 on 20080813. The curved lines are calculated trajectories that originate in or near the storm system and intercept near the flight path of the WB57. (From L. Pfister, NASA AMES).

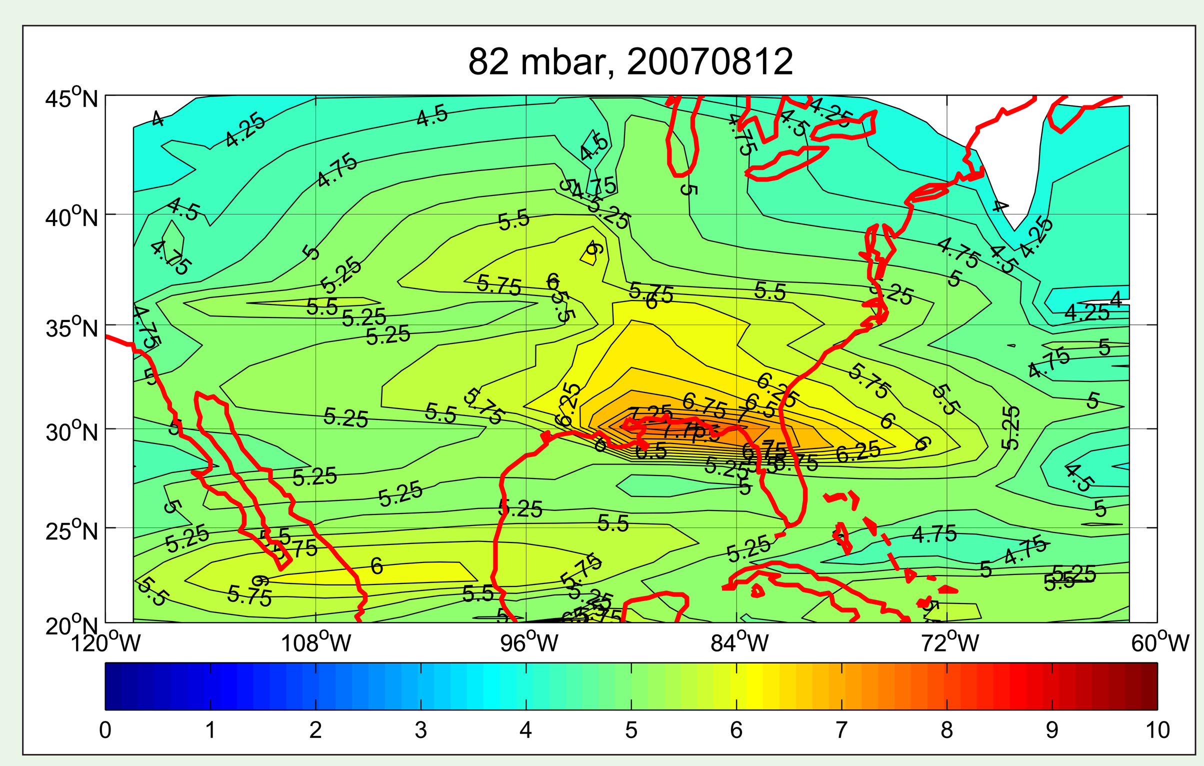


FIGURE 5. Observations of H_2O obtained the AURA MLS on 20080812 at 82 mbar. The large enhancement due to the storm over South Carolina is centered over Louisiana. The enhancements at other pressure levels (not shown) were observed up to 68 mbar on 20080812 and 20080813.

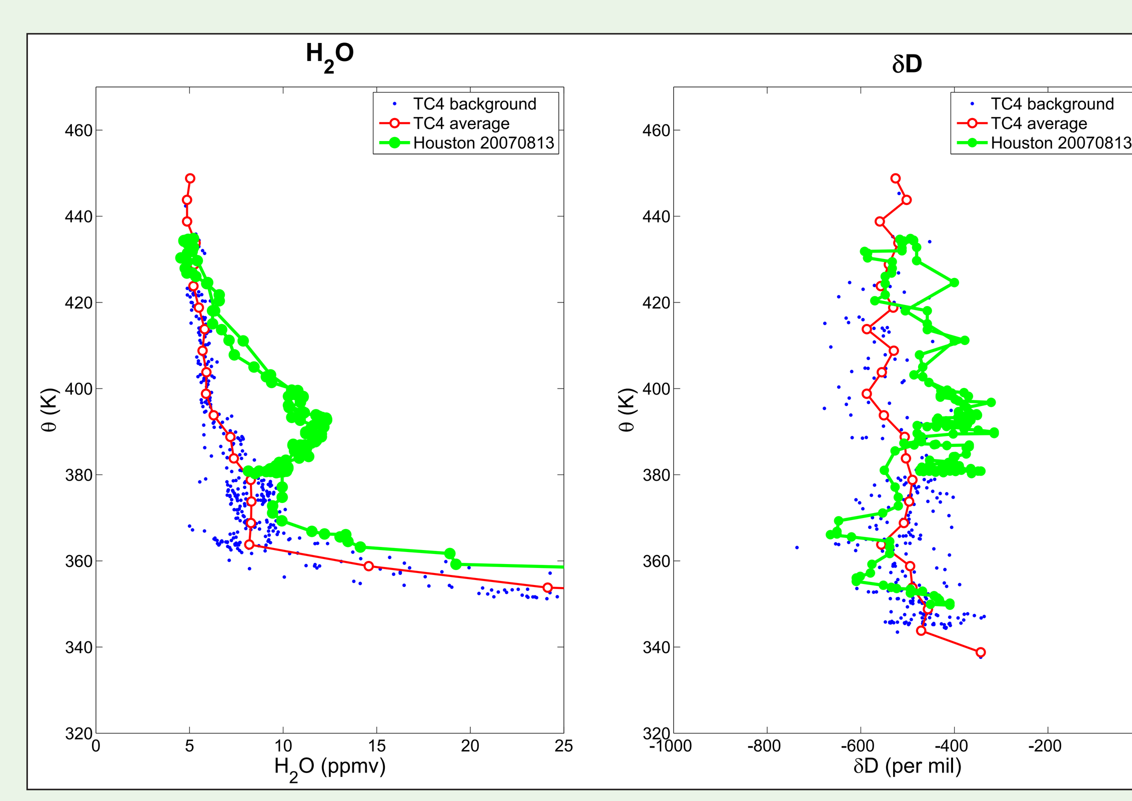


FIGURE 6. Observations of water isotope ratios and water vapor obtained by the Harvard Hoxotope instrument. The observations of the convective outflow obtained on 20080813 are superimposed on typical profiles for this region. A large enhancement of water vapor and δD are consistent with convective injection of ice.

This encounter showed a smaller perturbation to water and δD than others observed in AVE_WIIF, but the spatial extent was large enough to be captured by MLS. Observations like these have been obtained frequently (on about a third of the flights) on flights out of Houston in the summertime.

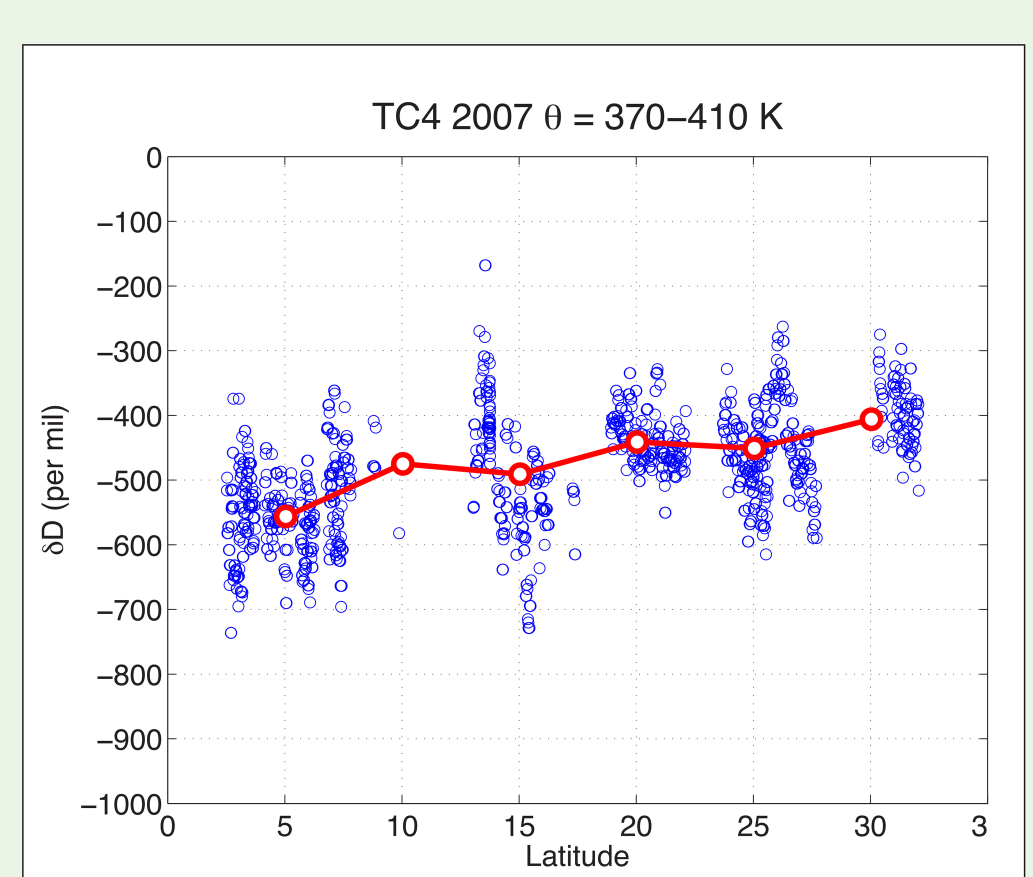


FIGURE 7. Observations of the vapor phase δD by the Harvard Hoxotope instrument obtained near θ = 380 K during TC4. The data show a gradient with latitude consistent with greater convective influence at higher latitudes. The oxidation of CH_4 is not significant at these altitudes.

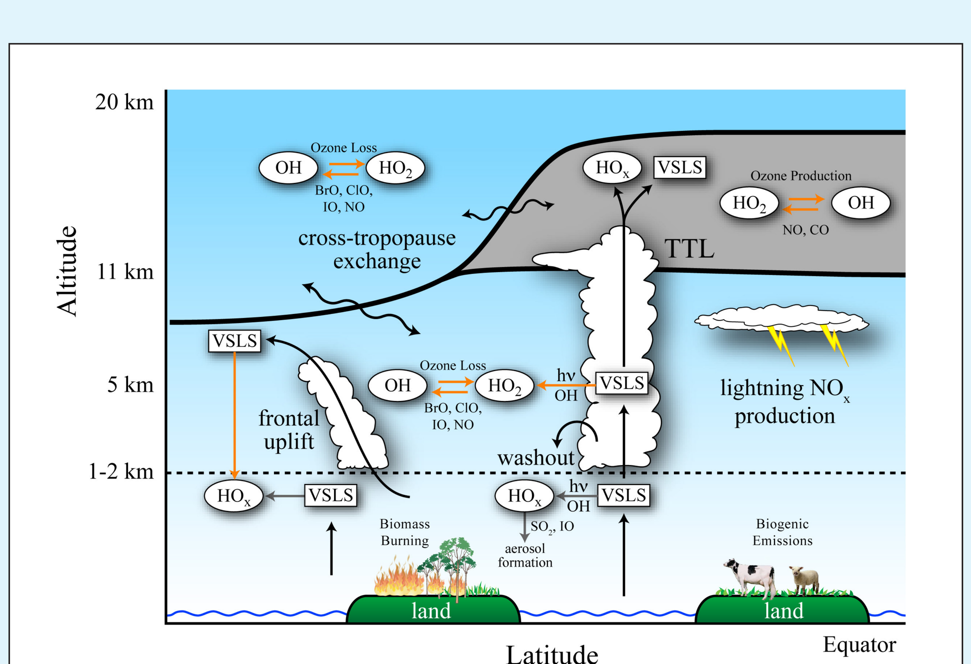
Summary

Deep convection injects water into the TTL and lower stratosphere.

In the TTL the observations can be explained by a model that relies on a temperature controlled mechanism. In this case water vapor is determined by the saturation mixing ratio. Convection enhances δD (i.e. HDO) without increasing H_2O.

In the mid-latitudes water vapor and water vapor ice are injected above the tropopause. The injection leads to an increase of HDO and H_2O as indicated by the increased δD.

This same mechanism may transport short lived species into the TTL and LS.



How does deep convection influence the abundance of

- HO_x? (e.g. HCHO Acetone)
- NO_x? (e.g. lightning)
- ClO_x? (e.g. $ClONO_2 + H_2O \rightarrow HOCl + HNO_3$)
- BrO_x? (e.g. CH_3Br)